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(54) Continuous etching method and apparatus therefor.

(57) A plurality of resist membranes are formed on a semiconductor wafer to be etched. The top resist is patterned by light beam, laser beam, X-rays, or electron beams to form a mask. The wafer is transferred to a first unit (2) into which discharging gas is introduced and plasma is generated in order to dry-etch the multilayer resists. The multilayer is transferred to a second unit (3) in a vacuum. In the second unit, the membrane of the wafer is dry-etched to a predetermined depth. The wafer then is transferred to a third unit (4) in a vacuum where part of the resist is removed according to the mask pattern and treatment of the resist by the plasma.

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# CONTINUOUS ETCHING METHOD AND APPARATUS THEREFOR

The present invention relates to a continuous etching method comprising the steps of forming a multilayer resist membrane on a member to be etched; patterning the top resist layer by means of, for example, light, x-ray or electronic line drawing; conveying the member to a first treatment region; introducing a gas to the first treatment region and generating a discharge plasma; dry-etching the multilayer resist; conveying the member to a second treatment region; dry-etching the member to a predetermined depth in the second treatment region; conveying the member to a third treatment region; and removing the resist according to the patterning and plasma treatment in the third treatment region.

The invention is particularly applicable to wafer dry etching steps in a semiconductor manufacturing process, including, for example, a dry etching step for etching a mask, a dry etching step for etching the wafer, and subsequent after-treatment.

According to the conventional dry etching process, a resist pattern or a mask used in the process has been created in an extra or different process and apparatus to that used for the wafer dry etching process itself. Ordinarily, a resist material is exposed to light and then a solution is used to carry out a development treatment. Nowadays, the depth of the resist pattern to be treated or generated is around 0.5  $\mu\text{m}$ , so that it becomes difficult to make a pattern of photo-resist by the conventional development method using a unilayer resist. Recently, in order to overcome the difficulty of the conventional development method, the resist has been made from a multilayer membrane. The top layer membrane is made flat, and the bottom layer of the resist must be vertically treated by oxygen plasma.

Concerning this so-called oxygen plasma method, it is desirable to treat or machine the resists by using low gas pressure with high accuracy in the notionally vertical direction and minimal horizontal shift.

However, practically speaking it is very difficult to reduce the amount of shift below about 0.1  $\mu\text{m}$ . Consequently, it is not practical to depend only on the oxygen plasma method and it is necessary to employ a side wall protective membrane forming process, as previously used in dry etching, in resist treatment. Such resist treatment requires the use of gases including chlorine.

Thus, various dry etching processes have been carried out individually using separate treatment appliances or separate treatment units.

After treatment the wafers are transferred in the atmosphere. However, when the wafer is exposed

to the atmosphere after treatment, in particular resist treatment with a gas containing chlorine, a base material to be etched is apt to corrode. As a result the dimensional precision after treatment is adversely affected or the desired precision is not achieved.

The reason for this corrosion seems to be that the halogen element, such as chlorine, remains on the top surface of the wafers and reacts with water in the atmosphere, generating acid. The acid then reacts with the etched material. The reactions are local cell effects, so that the material corrodes very quickly.

An object of the present invention is to provide an etching process and apparatus preventing the wafer from corroding and also to allow the manufacture of wafers with a high yield.

The present invention is characterised by conveying the member between the treatment regions in an evacuated environment.

The invention also extends to continuous etching apparatus comprising a vacuum conveying chamber, a load unit communicable with the vacuum conveying chamber through a first air-tight gate, an unload unit communicable with the vacuum conveying chamber through a second air-tight gate, a resist etching unit communicable with the vacuum conveying chamber through a third air-tight gate, and a further etching unit communicable with the vacuum conveying chamber through a fourth air-tight gate, an after-treatment unit communicable with the vacuum conveying chamber through a fifth air-tight gate, and conveying means in the vacuum conveying chamber arranged to convey articles between respective units.

These and other preferable features are defined in the accompanying claims.

The present invention can be put into practice in various ways some of which will now be described with reference to the accompanying drawings, in which :-

Fig.1 is a plan view of an embodiment of continuous etching apparatus according to the invention;

Fig.2 is a plan view of another embodiment;

Fig.3 is a similar view of still another embodiment; and

Fig.4 shows a section through a wafer.

The apparatus shown in Fig.1 consists of six units contained mainly within a pressure-reduced vessel.

The apparatus has a load unit 1, a resist etching unit 2, a plasma etching unit 3, an after-treatment unit 4, and an unload unit 5. The load unit 1 receives members to be treated (wafers) in the

atmosphere. The resist etching unit 2 for etching resist layers on the wafer has wafer temperature control means and an ion energy controller for generating plasma at a gas pressure of 1 mTorr. The plasma etching unit 3 for treating the material to be etched by a plasma etching process has wafer temperature control means (cooling means and/or heating means). The after-treatment unit 4 has heating means so as to carry out corrosion prevention treatment on the wafer by plasma or other source of heat located in a treatment table. The unload unit 5 unloads the treated wafers.

It will be noted that the load unit 1 and the unload unit 5 are air-tightly connected and placed at an upstream end and a downstream end, respectively, of an elongate vacuum conveying chamber 6 communicating through gate valves 7 and 8. The resist etching unit 2, the plasma etching unit 3 and the after-treatment unit 4 are air-tightly connected to a side face of the elongate vacuum conveying chamber 6 through gate valves 9, 10, and 11. Thus, the units 2, 3 and 4 can be isolated from one another and the conveying chamber 6 can isolate these units from the atmosphere.

The load unit 1 has a first cassette receiving stand 12 connected thereto and the unload unit 5 has a second cassette receiving stand 13 connected thereto. The first cassette receiving stand 12 has a transfer device 15 for transferring wafers 14 to the load unit 1, and the second stand 13 also has a transfer device 16 for taking the wafers out of the unload unit 5 and transferring them to a cassette (not shown) on the second stand 13.

In the vacuum chamber 6, there are: a first conveying unit 17, for conveying wafers 14 from the unload unit 5 to the resist etching unit 2; a second conveying unit 18, for conveying the wafers 14 between the resist etching unit 2 and the plasma etching unit 3; a third conveying unit 19, for conveying the wafers 14 between the plasma etching unit 3 and the after-treatment unit 4; and a fourth conveying unit 20, for conveying the wafers 14 between the unload unit 5 and the plasma etching unit 3.

The etching treatment procedure is as follows: First, the wafers 14 to be treated in the continuous etching apparatus are constructed as shown in Fig. 4. Each wafer consists of a silicon substrate 21, an oxidized membrane 22 on the substrate, an Al-0.5%Cu-Si membrane 23 of a thickness of about 1  $\mu$ m on the membrane 22, a photoresist layer 24 of a thickness of about 1.5  $\mu$ m on the membrane 23, a glass membrane 25 of about 0.1  $\mu$ m of spin on glass (SOG) liquid applied to the photoresist, and the top-layer of a photoresist mask 26 having a pattern formed by light, laser, X-rays or electron beam. The photoresist layer 24 is heat-treated at a temperature of 200°C.

The cassette storing the wafer 14 is as shown placed on the first cassette receiving stand 12. The wafer is then transferred from the cassette to the load unit 1 by means of the transfer device 15. According to this embodiment of the present invention, a suitable surface material of the wafer 14 is Al-Cu-Si.

The gate valve 7 is opened and the first conveying unit 17 takes the wafer 14 into the vacuum conveying chamber 6. During this time, the gate valves 9, 10 and 11, respectively, are kept closed.

When the gate valve 7 is closed, the vacuum conveying chamber 6 is evacuated. The wafer 14 is then conveyed to the resist etching unit 2 through the opened gate valve 9. Closing the gate valve 9, the gas mixture of oxygen and chlorine is supplied to the resist etching unit 2. Plasma is generated in the unit and the resist is etched while cooling the wafer 14. The time to complete the etching treatment is known or indicated by a light, luminous monitor or the like, connected to equipment monitoring the condition of the plasma.

After completion of the etching, the interior of the resist etching unit 2 is evacuated, the gate valve 9 opens, the first conveying unit 17 takes the wafer 14 out of the unit 2, and finally the gate valve 9 shuts. Next, the gate valve 10 of the plasma etching unit 3 opens and the etched wafer 14 is conveyed to the etching unit 3 by means of the second conveying unit 18. The gate valve 10 opens to allow the wafer in and is then shut. A plurality of chlorinous gases are supplied to the plasma etching unit 3 and plasma etching is carried out on the wafer 14 which is cooling during plasma etching. Again, the time of completion of plasma etching is indicated by a luminous monitor or the like. After completion of the etching treatment, the plasma etching unit 3 is evacuated, the gate valve 10 opens, the second conveying unit 18 takes the etched wafer 14 out of the unit 3, and finally the gate valve 10 shuts. Next, the gate valve 11 of the after-treatment unit 4 opens and the third conveying unit 19 conveys the etched wafer 14 to the after-treatment unit 4.

In the after-treatment unit 4, a treatment, mainly of O<sub>2</sub> plasma and heat treatment at about 200°C, removes the resist from the wafer. The after-treatment also applies a protective membrane. This protective membrane is preferably of a kind which is easily-removed from the inner wall of the after-treatment unit 4 during etching or removing the next resist, because the protective membrane also tends to coat that inner wall. It is also preferable to use a hydrocarbon-based gas including some hydrogen atoms as a reaction gas used in the after-treatment.

After completion of the after-treatment, the interior of the after-treatment unit 4 is evacuated, the

gate valve 11 opens, the third conveying unit 19 takes the wafer 14 out of the unit 19, and the gate valve 11 shuts. After ensuring that the gate valves 9, 10, and 11 are shut, the gate valve 8 opens to convey the treated wafer 14 to the unload unit 5 by the fourth conveying unit 20. The wafer 14 in the unload unit 5 is transferred to the cassette on the second cassette receiving stand 13 by the second transfer device 16.

When the treatment times of the resist etching, the plasma etching, and the after-treatment are different and the wafer proceeds through such steps sequentially, wafer waiting units 27 are used to queue the wafers 14 in order to diminish the time lag before treatment in the units.

Opening of the gate valves 7 and 8 placed at the upstream and downstream ends of the vacuum conveying chamber 6 is effected when the wafers 14 are loaded in respective units 2, 3 and 4. When the wafer 14 waits on the wafer waiting unit 27, no opening and closing of the gate valves 7 and 8 takes place in order to prevent the wafer 14 from becoming exposed to the atmosphere before completion of the series of the treatments.

It is of course possible to keep the gate valves 7 and 8 open, if the cassette receiving stand is arranged to place the wafer directly in the pressure-reduced vessel containing the load unit 1, the resist etching unit 2, the plasma etching unit 3, the after-treatment unit 4, the unload unit 5, and the vacuum conveying chamber 6 and the series of treatments are completed on each cassette before the next is loaded. This improves throughput of the continuous etching apparatus according to the present invention.

No corrosion is observed on the wafers if they are exposed to the atmosphere for 24 (twenty four) hours after being continuously treated by the etching method of the present invention and taken out of the unload unit 5.

Although the material to be etched in the embodiment above is Al-Cu-Si, it is possible to achieve corresponding effects when, for example, Si, Poly Si,  $\text{WSi}_2$  are used.

Also, the material to be etched in the embodiment above is a unilayer of Al-Cu-Si, but when the unilayer has a second layer membrane of TiW or W, an etching effect is apt to be insufficient if any etching is achieved at all, when using only a chlorinous gas mixture. This is because the etch speed of TiW and W is very slow in chlorinous gas. Consequently, it is preferable to etch such material in fluorine. However, Al-Cu-Si is not etched by fluorinous gas. It has been found that, when after Al-Cu-Si is etched in a gas mixture containing chlorine in a treatment chamber, the gas is replaced by a fluorinous gas which etches the TiW or W, the amount of dust produced increases. Under

these circumstances, when any combination of individual materials of a wafer respectively necessitate chlorinous gas and fluorinous gas atmospheres, two treatment chambers are preferable. Each material is treated in the particular chamber, thus decreasing total amount of dust to which the wafer is exposed at any time.

When Al-Cu-Si is etched in an individual chamber, the material is preferably heated to about  $80^\circ\text{C}$  before etching. W is preferably etched in an atmosphere at about  $-50^\circ\text{C}$ . In both cases, the features of etched and finished shapes, etching speeds, and selection ratios are excellent. When the material to be etched is Si or Poly Si, it is preferable to cool it to about  $-130^\circ\text{C}$ .

The wafers 14 are cooled in the resist etching step and the plasma etching step by various systems of liquified nitrogen and a controllable heater or by various refrigerator and controllable heater systems. The former system is suitable for a heating range from  $-150^\circ\text{C}$  to  $-80^\circ\text{C}$ . The latter system is preferable for a temperature from  $-80^\circ\text{C}$  to  $0^\circ\text{C}$ . In the after-treatment step of the process, heating means, rather than cooling means, are required. It is preferable to have control in the range from room temperature to about  $250^\circ\text{C}$ .

According to the embodiment of the present invention, in which the etching is carried out after the material is cooled, the absorption efficiency of the gases will become high, so that it is permitted to lower the flow rate and partial pressure of, in particular, a deposition gas. In practice, it is possible to carry out precise etching without dimensional shifts with only oxygen plasma when no chlorinous gas is blended with the oxygen and the temperature of the material or wafers is maintained at  $-100^\circ\text{C}$ .

Because the treatment effect of etching according to the present invention does not decrease even the flow rate or pressure of the deposition gas, the amount of dirt becoming stuck on the walls of the vacuum or pressure-reduced vessel is considerably reduced and a cleaner system of semiconductor manufacture and apparatus therefor can be realised. It is of course the case that the effective temperature of the wafer depends on the kind of deposition gas used.

Fig.2 shows another arrangement of various units of a continuous etching apparatus according to the present invention. As shown, the resist etching unit 2, the plasma etching unit 3, and the after-treatment unit 4 are placed around the vacuum conveying chamber 6.

Fig.3 shows still another arrangement, in which the various treatment units 2, 3 and 4 are connected through two vacuum chambers 6 and 6'.

It will be appreciated that the same parts and features of the apparatus, respectively shown in

Figs. 1, 2 and 3 have the same reference numerals.

According to the present invention, a series of etching treatments to be carried on the material to be etched are done in a vacuum without exposure to the atmosphere, so that no corrosion is experienced by the wafer. This results in improved etching and machining precision and improved yields of the product. Compared with the conventional after-treatment for preventing the wafer from corroding in the atmosphere, the unique corrosion prevention method of the present invention, which employs a protective membrane finally applied on the top of the wafer, necessitates the least number of deposition membranes. The membrane used is easily removed just before the step following its application. Owing to the effect of the continuous vacuum treatment of the present invention, it is possible to decrease considerably the dirt on the wafer and dust generation in the environment, leading to high reliability components made from wafers so etched.

#### Claims

1. A continuous etching method comprising the steps of :  
forming a multilayer resist membrane on a member to be etched;  
patterning the top resist layer by means of, for example, light, x-ray or electronic line drawing;  
conveying the member to a first treatment region (2);  
introducing a gas to the first treatment region and generating a discharge plasma;  
dry-etching the multi layer resist;  
conveying the member to a second treatment region (3);  
dry-etching the member to a predetermined depth in the second treatment region;  
conveying the member to a third treatment region (4); and  
removing the resist according to the patterning and plasma treatment in the third treatment region;  
characterised by conveying the member between the treatment regions in an evacuated environment.
2. A method as claimed in claim 1, wherein the member to be etched consists of a plurality of layers and, when respective layers cannot be etched in the same gaseous environment, performing each etching step in an individual treatment region.
3. A method as claimed in claim 2, wherein the respective gaseous environments of the individual treatment regions are fluorinous and chlorinous.
4. A method as claimed in claim 1, 2 or 3, including heat treating the member simultaneously with

removal of the resist in the third treatment unit and plasma treating the member so as to form a protective cover.

5. A method as claimed in claim 4, wherein the reaction gas for generating the protective cover is hydrocarbon-based.
6. Continuous etching apparatus comprising a vacuum conveying chamber (6), a load unit (1) communicable with the vacuum conveying chamber through a first air-tight gate (7), an unload unit (5) communicable with the vacuum conveying chamber through a second air-tight gate (8), a resist etching unit (2) communicable with the vacuum conveying chamber through a third air-tight gate (9), and a further etching unit (3) communicable with the vacuum conveying chamber through a fourth air-tight gate (10), an after-treatment unit (4) communicable with the vacuum conveying chamber through a fifth air-tight gate (11), and conveying means (17,18,19,20) in the vacuum conveying chamber arranged to convey articles between respective units.
7. Apparatus as claimed in claim 6, wherein the resist etching unit and the further etching unit, each comprises cooling means, and the after-treatment unit comprises heating means.
8. Apparatus as claimed in claim 7, wherein the cooling means comprise a liquified nitrogen-based cooler and a heater.
9. Apparatus as claimed in claim 7, wherein the cooling means comprises a refrigerator and a heater.
10. Apparatus as claimed in any of claim 6 to 9, further comprising a waiting unit (27) in the vacuum conveying chamber in which members to be etched can be queued during conveyance between units.

FIG.1

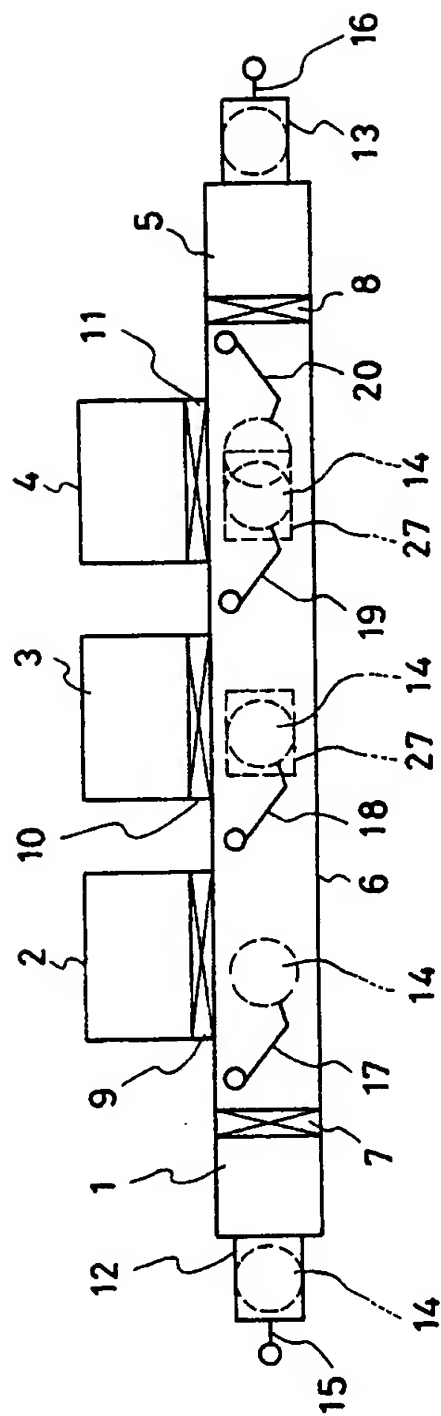


FIG.2

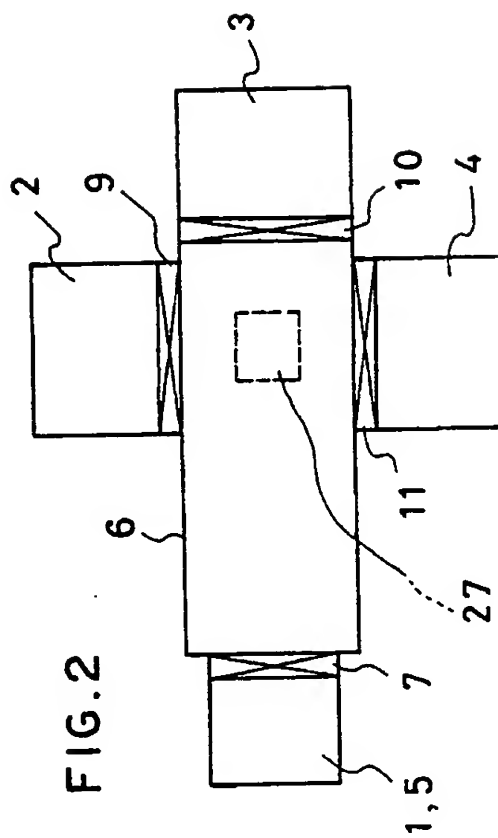


FIG.3

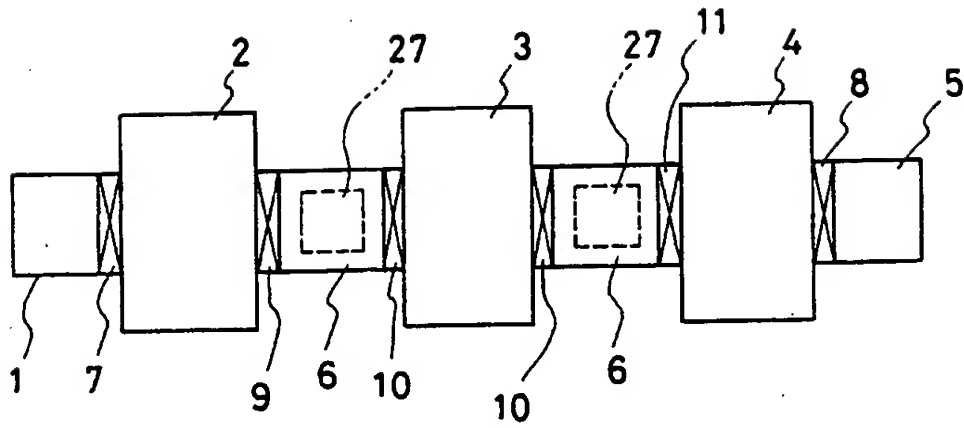


FIG.4

